TITLE

"A STRUCTURAL ELEMENT"

FIELD OF THE INVENTION

This invention relates to a structural element. In particular, the invention relates to a structural element constructed of polymer concrete.

BACKGROUND OF THE INVENTION

Developments in civil engineering and the building industry have created a continual demand for building materials with new and improved performance attributes. Polymer concretes offer possibilities for meeting these new requirements.

Polymer concrete consists of aggregates bonded together by a resin binder instead of a cement binder that is used in standard cement concrete. Polymer concrete has generally good durability and chemical resistance and is therefore used in various applications such as in pipes, tunnel supports, bridge decks and electrolytic containers. Additional advantages of polymer concrete includes very low permeability and very fast curing times. The compressive and tensile strength of polymer concrete is generally significantly higher than that of standard concrete.

As a result, polymer concrete structures are generally smaller and significantly lighter than equivalent structures made out of standard concrete. However, due to the relatively low Modulus of Elasticity of polymer concrete, compared to standard concrete, polymer concrete structures have a tendency to deflect significantly more than equivalent standard concrete structures.

As with standard concrete, polymer concrete structures generally require reinforcement to carry the tensile loads. Even though reinforcement is effective in carrying tensile forces, in many situations it cannot prevent cracks from occurring in the tensile zone of a polymer concrete member. Traditional steel reinforcement bars can be used in a polymer concrete structure but as polymer concrete is often used in corrosive environments, these cracks can lead to corrosion of steel reinforcement.

Composite reinforcement has also been used in polymer

concrete to address the corrosion problem of steel reinforcement. The composite reinforcement used has the same shape as steel reinforcement bars, i.e., ribbed or circular bars. However, cracks generally result in serious stress concentrations at the locations of the cracks which, due to the brittle nature of composite reinforcement, can lead to premature failure of the composite reinforcement. The latter is of particular concern in dynamic loading environments.

In addition, cracks can seriously affect the aesthetics of the polymer concrete members and lead to safety concerns in the general public. In traditional concrete structures, prestressing of the reinforcement has been used to assist in preventing cracking from occurring within the concrete structure. Two different methods are widely used for this purpose namely post-tensioning and pre-tensioning.

In post-tensioning the reinforcement is tensioned after the concrete has hardened. The reinforcement is not bounded to the surrounding concrete at the time of prestressing, but is placed in special ducts that pass through the member. At one end, the reinforcement is anchored to the hardened concrete using a localised anchor, and at the other end it is jacked against the concrete until the required level of prestress is obtained and then locked off. Upon completion the ducts may or may not be pressure grouted.

A member is pre-tensioned if the prestressing reinforcement is tensioned before the concrete is cast. The reinforcement is tensioned between two end abutments and then the concrete is cast. When the concrete has attained sufficient strength, the prestressing force is released from the abutments. As the reinforcement attempts to contract elastically, the concrete is forced into compression. Slipping of the reinforcement inside the concrete is prevented through ribs on the reinforcement or spiral twists in the prestressing cables which generally consist of many individual wires. These wires are often crimped or indented in order to approve the bonding characteristics.

Both of the above methods of tensioning work well. However,

even though concrete cracks can be prevented by prestressing, concrete is porous and water and chemicals may still reach the steel prestressing reinforcement and cause corrosion, particularly in salt water environments.

In order to alleviate possible corrosion of the steel prestressing reinforcement, composite reinforcement has also been used for the prestressing of concrete structures. Both the post-tensioning and pre-tensioning approach has been used with composite reinforcement. However, due to the limited strength of fibre composite reinforcement perpendicular to the fibre direction, longitudinal splitting and transverse crushing at the anchors is common when using the post-tensioning method.

Worldwide, research is continuing to develop special anchors for fibre composite post-tensioning reinforcement. In the pre-tensioning process, it is difficult to obtain adequate anchorage/bonding between the fibre composite reinforcement and standard concrete due to the difficulties associated with providing the composite reinforcement with adequate ribbing to prevent slippage.

Some examples of the attempts to use fibre composite for pre-tensioning of standard concrete are described in US 2004/0130063 and JP 5239885. In US 2004/0130063 a method of pre-stressing utilises a variety of anchors and rings are used to grip the concrete in order to achieve pre-stressing. In JP 5239885 a foamable resin is used to create a composite fibre reinforcement bar of an uneven shaped. Due to the uneven shape, composite reinforcement bar is used to grip the concrete in order to achieve pre-stressing. However, to date, there has been limited use of fibre composite reinforcement for the pretensioning process.

OBJECT OF THE INVENTION

It is an object of the invention to overcome or alleviate one or more of the above disadvantages or provide the consumer with a useful or commercial choice.

It is a preferred object of this invention to produce structural elements made from polymer concrete with significantly improved crack resistance.

It is a further preferred object of the invention to produce polymer concrete structures with improved deflection behaviour.

It is a still further preferred object of the invention to produce polymer concrete structures with improved recovery after overload.

It is a still further preferred object of the invention to produce polymer concrete elements with improved strength in shear and torsion.

It is a still further preferred object of the invention to produce polymer concrete elements with improved fatigue resistance.

It is a still further preferred object of the invention to allow structural elements made of polymer concrete to be produced cost effectively.

SUMMARY OF THE INVENTION

In one form, although not necessarily the only or broadest form, the invention resides in a structural element comprising:

at least one pre-tensioned fibre reinforced plastic reinforcement member, the pre-tensioned fibre reinforced plastic reinforcement member having a constant cross-section through a length of the reinforcement; and

a polymer concrete member surrounding said pre-tensioned fibre reinforced plastic reinforcement member;

wherein a force transfer between the fibre reinforced plastic reinforcement member and the castable material is through polymer adhesive bonding.

Preferably, a ratio of a perimeter length of the pre-tensioned fibre reinforced plastic reinforcement member over the cross sectional area of the pre-tensioned fibre reinforced plastic reinforcement member is significantly larger than a ratio of a perimeter length over the cross sectional area of a circular bar having the same cross sectional area. This is to reduce the magnitude of shear stresses in a contact area between the reinforcement and the polymer concrete.

Preferably a ratio of a perimeter length of the pre-tensioned fibre reinforced plastic reinforcement member over the cross sectional area of the pre-tensioned fibre reinforced plastic reinforcement member is at least

one-third larger than a ratio of a perimeter length over the cross sectional area of a circular bar having the same cross sectional area.

More preferably, a ratio of a perimeter length of the pre-tensioned fibre reinforced plastic reinforcement member over the cross sectional area of the pre-tensioned fibre reinforced plastic reinforcement member is at least one half larger than a ratio of a perimeter length over the cross sectional area of a circular bar having the same cross sectional area.

Still more preferably, a ratio of a perimeter length of the pre-tensioned fibre reinforced plastic reinforcement member over the cross sectional area of the pre-tensioned fibre reinforced plastic reinforcement member is at least double a ratio of a perimeter length over the cross sectional area of a circular bar having the same cross sectional area.

Yet still more preferably, a ratio of a perimeter length of the pre-tensioned fibre reinforced plastic reinforcement member over the cross sectional area of the pre-tensioned fibre reinforced plastic reinforcement member is at least quadruple a ratio of a perimeter length over the cross sectional area of a circular bar having the same cross sectional area.

Preferably, a suitable perimeter/area ratio is achieved by using fibre reinforced plastic reinforcement members with a thin walled cross section. The fibre reinforced plastic reinforcement members may be solid or hollow.

Preferably, the wall thickness of the pre tensioned fibre reinforced plastic reinforcement member is between 1 and 5 mm.

The structural element may include at least one non pre-tensioned fibre reinforced plastic reinforcement member.

The level of pretension in the fibre composite reinforcement can vary from 0 up to almost 80 - 100% of the ultimate tensile strength of the reinforcement.

Preferably the level of pretension in the reinforcement is between 20-50% of the ultimate tensile strength of the reinforcement member.

The fibre reinforced plastic reinforcement members may be

produced from any suitable glass, carbon or aramid fibre and/or plastic material dependant upon the desired properties of the structural element. Preferably, the surface area of the fibre reinforced plastic reinforcement members that contact the castable material is abraded to increase adhesion between the castable material and the fibre reinforced plastic reinforcement members. Alternatively, the fibre reinforced plastic reinforcement members may be coated with a sand and/or gravel interface to increase adhesion.

The pre-tensioned fibre reinforced plastic reinforcement members may be pultruded fibre reinforced plastic. Preferably, the fibre reinforced plastic reinforcement members have flat surfaces to simplify the sanding or abrading process. The reinforcing members may be hollow to save maximum weight.

In one embodiment, the pultruded, pre-tensioned fibre reinforced plastic reinforcement members may be filled with standard concrete, polymer concrete or a filled resin system and a metal or fibre composite reinforcing bar to further increase their load carrying capacity and stiffness.

In another embodiment the hollow, pultruded, pre-tensioned fibre reinforced plastic reinforcement members may be filled with other materials dependant upon the desired properties of the tubular reinforcing element.

The hollow pultruded, pre-tensioned fibre reinforced plastic reinforcement members may be filled before or after the pre-tensioning of the members. Preferably the members are filled after the pre-tensioning of the fibre reinforced plastic reinforcement members.

The fibre reinforced plastic members may extend longitudinally and transversely through the structural element. One or more of the longitudinal and/or transverse fibre reinforced plastic members may be pre-tensioned.

The transverse fibre reinforced plastic members may pass through the longitudinal fibre reinforced plastic members.

Slots may be located in either or both of the transverse and

longitudinal fibre reinforced plastic reinforcement members to allow them to intersect. The longitudinal fibre reinforced plastic members and transverse fibre reinforced plastic members may be locked to each other after they intersect.

Notches may be provided in the longitudinal fibre reinforced plastic reinforcement members and/or transverse fibre reinforced plastic reinforcement members to engage with the slot on the other of the members to lock the members together.

The polymer concrete formulation may include an amount of polymer resin, an amount of a light aggregate with a specific gravity less than that of the resin and an amount of a heavy aggregate with a specific gravity larger than that of the resin.

The resin may be any suitable polyester, vinylester, epoxy, phenolic or polyurethane resin or combination of resins dependent on the desired structural and corrosion resistant properties of the polymer concrete. Preferably, the resin content is between 25-30% by volume.

The light aggregate with a specific gravity less than that of the resin can be any type of light aggregate or combination of light aggregates dependent on the desired structural and corrosion resistant properties of the polymer concrete. Usually, the light aggregates have a specific gravity of 0.5 to 0.9. The light aggregates usually make up 20-25% by volume of the polymer concrete. Preferably, the light aggregate are centre spheres. The centre spheres normally have a specific gravity of approximately 0.7. Alternately, hollow glass microspheres with a similar specific gravity and volume may be used.

The heavy aggregate with a specific gravity larger than that of the resin can be any type of heavy aggregate or combination of heavy aggregates dependent on the desired structural and corrosion resistant properties of the polymer concrete. The heavy aggregates usually make up 40-60% by volume of the polymer concrete. The heavy aggregate has a specific gravity of between 2 to 3.5.

Preferably the heavy aggregate is basalt. Usually the basalt is

crushed. The crushed basalt may have a particle size 1 to 7 mm. Preferably the basalt makes up between 40-50% by volume of the polymer concrete. The basalt normally has a specific gravity of approximately 2.8. Alternately, natural or artificial sand, that has a similar specific gravity as basalt, may be used. Preferably the sand makes up between 50-60% by volume of the polymer concrete.

Alternatively, the heavy aggregate may be made up of one or more of coloured stones, gravel, limestone, shells, glass or the like material.

Preferably the resin contains a thixotrope to keep the light aggregate in suspension.

The polymer concrete of the present invention may also include fibrous reinforcement material to increase the structural properties of the polymer concrete mix. The reinforcement material may be glass, aramid, carbon, timber and/or thermo plastic fibres.

In another form, the invention resides in a method of producing a structural element formed from polymer concrete, said method including the steps of:

producing a mould that has a portion of an outer shape of the structural element to be produced;

placing fibre reinforced plastic members within the mould, tensioning at least one of the fibre reinforced plastic members;

locating polymer concrete over said fibre reinforced plastic members;

allowing said castable material to set to form said structural element; and

releasing said pre-tensioned members after the castable material has set to form said structural element.

The fibre reinforced plastic members may be abraded prior to the fibre reinforced plastic members being introduced into the mould. Alternatively, the fibre reinforced plastic members may be coated with sand and/or gravel interface to increase adhesion.

In one embodiment, the fibre reinforced plastic members may

be located within the mould tensioned and polymer concrete poured over the fibre reinforced plastic members.

In another embodiment, the fibre reinforced plastic members may be located within the mould after sufficient castable material to complete the structural element has been delivered into the mould. At least one of the fibre reinforced plastic members may be tensioned before the polymer concrete sets.

In still another embodiment, a portion of polymer concrete may be introduced into the mould and some of the fibre reinforced plastic members introduced into the mould and pretensioned. More polymer concrete may then be introduced into the mould and more fibre reinforced plastic members may be introduced into the mould and pretensioned. This process may be continued until the structural element has been completed.

Where the fibre reinforced plastic members are hollow, the hollow fibre reinforced plastic members may be filled with concrete, polymer concrete or filled resin system and/or metal or reinforced plastic bar. The hollow fibre reinforced plastic members may be filled after tensioning of the hollow fibre reinforced plastic members. Normally, the hollow fibre reinforced plastic members are filled after the tensioning has been removed and the polymer concrete has set.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the invention, by way of examples only, will be described with reference to the accompanying drawings in which:

FIGS. 1A to 1D are transverse cross-sectional views of fibre reinforced plastic reinforcement members that have large ratios of perimeter length over cross sectional area resulting in reduced shear stresses in the contact area and hence are suitable for pre-tensioning;

FIGS. 2A to 2C are transverse cross-sectional views of fibre reinforced plastic reinforcement members that have small ratios of perimeter length over cross sectional area which result in much higher stresses in the contact area and hence are far less suitable for pre-tensioning;

FIG. 3 is a perspective view of a beam according to a first

embodiment of the invention;

FIGS. 4A to 4F are side cross-sectional views of the beam of FIG. 3A being formed;

FIG. 5 is a perspective view of a park bench slat according to a second embodiment of the invention;

FIG. 6 is a perspective view of a telephone pole according to a fourth embodiment of the invention;

FIG. 7 is a perspective view of another beam according to a third embodiment of the invention; and

FIG. 8 is a perspective view of a of yet another beam according to a fifth embodiment of the invention;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

FIGS. 1A to 1D and FIGS. 2A to 2C show transverse cross-sectional views of fibre reinforced plastic reinforcement members 20. As is shown, various shapes of fibre reinforced plastic reinforcement members may be used.

FIGS. 1A to 1D illustrate fibre reinforced plastic reinforcement members that are suitable for use to produce a prestressed structural element. The reasons that each of the fibre reinforced plastic reinforcement members shown are able to be used is due to the fact that low stresses occur throughout the members when located in a structural element. On the other hand, the shear stress that occurs in the fibre reinforced plastic reinforcement members shown in FIGS. 2A to 2C upon pre-tensioning is considerable and hence they are much more likely to fail at low loads causing failure of the corresponding structural element. In addition, the fibre reinforced members shown in FIGS. 2A to 2C are very vulnerable to suffer major damage if penetrated by bolts, screws and/or nails.

The fibre reinforced plastic reinforcement members of FIGS. 1A to 1D operate effectively as a perimeter length 21 of each of the fibre reinforced plastic reinforcement members is relatively large compared to the cross-sectional area 22. The fibre reinforced plastic reinforcement members shown in FIGS. 2A and 2B have a relatively low perimeter length

21 when compared to the cross-sectional area 22. The large perimeter length of the fibre reinforced plastic reinforcement members shown in FIGS. 1A to 1D provide a large adhesion surface or a contact area to which a polymer concrete is able to adhere to the fibre reinforced plastic reinforcement members 20. This adhesion can be enhanced by abrading the contact area of the fibre reinforced plastic reinforcement members.

The perimeter/area ratio has been calculated for each of the fibre reinforced plastic reinforcement members shown in FIGS. 1A, 1B and 2B. Each of the fibre reinforced plastic reinforcement members have the same cross sectional area and hence the same theoretical tensile strength.

	FIG 1A	**FIG 1B**	**FIG 2B**
Dimensions	Width = 300 mm Height = 3 mm	Width = 50 mm Height = 50 mm Thickness = 5 mm	Diameter = 33.85 mm
Cross-Sectional Area	900 mm^2	900 mm^2	900 mm^2
Perimeter Length	606 mm	200 mm	106 mm
P/A Ratio	0.673 mm^{-1}	0.222 mm^{-1}	0.117 mm^{-1}

For the thin walled cross sections the perimeter/area ratio is significantly larger then for the solid circular cross section.

FIG. 3 shows a structural element in the form of a prestressed concrete beam 300. The concrete beam is formed from polymer concrete 30 that surrounds a square tubular fibre reinforced plastic reinforcement member 20 that extends the length of the beam. Additional polymer concrete 40 is located within the fibre reinforced plastic reinforcement member 20 and a steel reinforcement bar 50 is imbedded within the polymer concrete 40 and extends the length of the fibre reinforced plastic

reinforcement member 20.

FIGS. 4A to 4F show the process that is used to form the prestressed beam 300 of FIG. 3. In order to produce the prestressed beam 300, a mould 60 is produced. The fibre reinforced plastic reinforcement member 20 is then tensioned. The tensioning of the fibre reinforced plastic reinforcement member 20 can be conducted in any number of ways but generally involves placing a clamp on either end of the fibre reinforced plastic reinforcement member 20 and applying opposing forces to the fibre reinforced plastic reinforcement member 20 as indicated by arrows.

Once the fibre reinforced plastic reinforcement member 20 has been tensioned, it is located within the mould as shown in FIG. 4A. Polymer concrete 30 is then poured into the mould as shown in FIG. 4B until the entire fibre reinforced plastic reinforcement member is covered as shown in FIG. 4C.

At this point, the polymer concrete 30 is allowed to set. Once the polymer concrete 30 has set then the tensioning of the fibre reinforced plastic reinforcement member 20 is released to create a beam 300 that is prestressed. At this point, if the fibre reinforced plastic reinforcement member 20 extends past the end of the beam, it can then be cut so that the end of the fibre reinforced plastic reinforcement member 20 is flush with the ends of the beam 300.

To add additional strength to the beam 300, the additional steps of FIGS. 4D and 4E can be completed. In FIG. 4E, polymer concrete 40 is added within the fibre reinforced plastic reinforcement member 20. FIG. 4F shows that the addition of a steel reinforcement bar 50 can also be added. By adding the polymer concrete 40 and the reinforcement bar 50, the stiffness, strength and ductility properties of the beam are significantly increased.

FIG. 5 is a structural element in the form of a prestressed polymer concrete slat 400 that can be used for park benches. In this embodiment, the fibre reinforced plastic reinforcement member 20 is a flat planar member that extends the length of the slat and is surrounded by

polymer concrete 30.

FIG. 6 shows a structural element in the form of a prestressed concrete telegraph pole 500. In this embodiment, several square tubular fibre reinforced plastic reinforcement members 20 are utilised to form the telegraph pole. The fibre reinforced plastic reinforcement members are surrounded by polymer concrete 30 to form the telegraph pole 500.

FIG. 7 is a structural element in the form of another prestressed concrete beam 700.

In this embodiment different fibre reinforced plastic reinforcement members are used. A single flat planar fibre reinforced plastic reinforcement member 24 and four square tubular fibre reinforced plastic reinforcement members 25 are used to form the beam. All of the fibre reinforced plastic reinforcement members are pre-tensioned as discussed previously. A series of ligatures 26 are located around the fibre reinforced plastic reinforcement members to assist in tying the fibre reinforced plastic reinforcement members together and to provide lateral confinement to the beam 700.

In FIG. 8, a further prestressed reinforcement beam 800 is shown. In this embodiment the beam 800 has a standard concrete top 70 and a polymer concrete base 30. A series of square tubular fibre reinforced plastic reinforcement members 20 are located within the polymer concrete. Two ligatures 26 extend through the traditional concrete 70 and the polymer concrete 30 and extend around the fibre reinforced plastic reinforcement members 20 to tie the traditional concrete 70, polymer concrete 30 and fibre reinforced plastic reinforcement members 20 together. The beam 800 is also produced so that a hollow 80 extends through the beam 800 to make the beam 800 lighter. This hollow may be created by using a sacrificial foam void former.

It should be appreciated that during installation of any of the above structural members, holes are often made into the member to accommodate bolts, screws, and/or nails. Because of their elongated cross sectional geometry, thin walled solid and hollow fibre composite

reinforcement members spread the reinforcement fibres over a large area of the cross section of the structural member, hence the damage caused by bolt holes, screws and/or nails is generally limited to a small number of individual fibres. In the case of thick walled solid reinforcement members, all fibres are bundled together in a small area, hence a bolt or screw that penetrates this area will damage a large number of reinforcement fibres and will cause major damage to the reinforcement member which might lead to failure.

In each of the above examples, the contact area provided by the external surface of the fibre reinforced plastic reinforcement members is sufficiently large so that the polymer concrete is able to adhere to the surface of the fibre reinforced plastic reinforcement members without creating large shear stress. As the thickness of the fibre reinforced plastic reinforcement members is also relatively small, the shear stress within the fibre reinforced plastic reinforcement members is relatively small. This allows the fibre reinforced plastic reinforcement members to be pre-tensioned in order to create prestressed structural elements.

It should be appreciated that the polymer bond that is formed between the polymer concrete and the fibre reinforced plastic reinforcement members is high i.e. approximately 50 MPA. This enables fibre reinforced plastic reinforcement members to be used to pre-stress polymer concrete that previously has not been able to be achieved. Further, by increasing the surface of the fibre reinforced plastic reinforcement members that contacts the polymer concrete, the polymer bond formed between the polymer concrete and the fibre reinforced plastic reinforcement members is increased.

It should be appreciated that various other changes and modifications may be made to the embodiments described without departing from the spirit or scope of the invention.